<u>5.17.08</u> <u>COMPARISON OF QUALITY CONTROL AND VERIFICATION TESTS</u>

This procedure is carried out to compare two different sets of multiple test results for finding the same parameter. Typical example would be comparing contractor QC test results and KDOT verification test results to determine if the material under test came from the same population. The statistical test which would be used to compare two means would be popularly known as Student's t-test or simply t-tests for testing a null hypothesis (H_0) with certain confidence (e.g. 99%) or level of significance (risk of rejecting a null hypothesis when it is true, e.g., 1%) is as follows:

H_o : There is no difference in the sample means, ie. the means are statistically equal

If the test results do not support this hypothesis than an alternate hypothesis (H_a) is accepted as:

H_a: The means are different, ie. the means are not statistically equal

This test is generally applicable when the number of tests (or observations as is known in Statistics) is less than or equal to 30. However, since the approach used in the t-test is dependent upon whether or not the variances (square of the sample standard deviation) are equal for the two sets of data, it is necessary to test the variances of the test results before comparing the means of the test results.

F-test for the Sample Variances

The F-test determines whether the difference in the variability of the contractor's QC tests and that of KDOT's verification tests is larger than might be expected from chance if they came from the same population. In this case, a hypothesis testing is done at a certain level of significance. The null hypothesis in the test is:

H_o: There is no difference in the sample variances, ie. the variances are statistically equal

If the test results do not support this hypothesis than an alternate hypothesis is accepted as:

H_a: The variances are different, i.e. the variances are not statistically equal

The following steps need to be followed in doing an F-test:

i) Compute the variance (the standard deviation squared) for the QC tests, s_c^2, and the KDOT verification tests, s_v^2

ii) Compute F statistic as:

$$F = s_c^2 / s_v^2 \text{ or } s_v^2 / s_c^2$$

Always use the larger of the two variances in the numerator.

iii) Choose the level of significance, α, for the test. The recommended α is 1%.

iv) Find the critical F value F_{crit}, from the Table 5.17.08-1 using the degrees of freedom associated with each set of test results. The degrees of freedom for each set of results is the number of test results in the set, less one. If the number of QC tests *is* n_c and the number of verification tests is n_v, then the degrees of freedom associated with s_c^2 is $(n_c\text{-}1)$ and the degrees of freedom associated with s_v^2 is $(n_v\text{-}1)$. The values in Table 5.17.08-1 are tabulated to test if there is a difference (either larger or smaller) between two variance estimates. This is known as a two-sided or two-tailed test. Care must be taken when using other tables of the F distribution , since they are usually based on a one-tailed test, ie., testing specifically whether one variance is larger than another. <u>When finding F_{crit} be sure that the appropriate degrees of freedom for the numerator and denominator are used.</u>

v) Find the value for F_{crit} from Table 5.17.08-1.

vi) If $F \geq F_{crit}$, then the null hypothesis is rejected i.e. the two sets of tests have significantly different variabilities. If $F < F_{crit}$ then there is no reason to believe that the variabilities are significantly different.

t-test for Sample Means

Once the variances have been tested and been assumed to be either equal or not equal, the means of the test results can be tested to determine whether they differ from one another or can be assumed equal. The desire is to determine whether it is reasonable to assume that the QC tests came from the same population as the verification tests. As mentioned before, a t-test is used to compare the sample means. Two approaches for the t-test are necessary.

If the sample variances are assumed equal, then the t-test is conducted based on the two samples using a *pooled estimate for the variance* (s_p^2) and the pooled degrees of freedom. If the sample variances are found to be different in the F-test, the t-test is conducted using the individual sample variances, the individual sample sizes, and the effective degrees of freedom <u>(estimated from the sample variances and sample sizes)</u>.

In either of the two cases discussed earlier, the null hypothesis used is:

> H_o : *There is no difference in the sample means, i.e. the means are statistically equal*

If the test results do not support this hypothesis than an alternate hypothesis is accepted as:

> H_a: *The means are different, i.e. the means are not statistically equal*

Table 5.17.08-1 **Critical Values, F_{crit} for the F-test for a Level of Significance, α =1%**

DEGREES OF FREEDOM FOR NUMERATOR

DEGREES OF FREEDOM FOR DENOMINATOR

	1	2	3	4	5	6	7	8	9	10	11	12
1	16200	20000	21600	22500	23100	23400	23700	23900	24100	24200	24300	24400
2	198	199	199	199	199	199	199	199	199	199	199	199
3	55.6	49.8	47.5	46.2	45.4	44.8	44.4	44.1	43.9	43.7	43.5	43.4
4	31.3	26.3	24.3	23.2	22.5	22.0	21.6	21.4	21.1	21.0	20.8	20.7
5	22.8	18.3	16.5	15.6	14.9	14.5	14.2	14.0	13.8	13.6	13.5	13.4
6	18.6	14.5	12.9	12.0	11.5	11.1	10.8	10.6	10.4	10.2	10.1	10.0
7	16.2	12.4	10.9	10.0	9.52	9.16	8.89	8.68	8.51	8.38	8.27	8.18
8	14.7	11.0	9.60	8.81	8.30	7.95	7.69	7.50	7.34	7.21	7.10	7.01
9	13.6	10.1	8.72	7.96	7.47	7.13	6.88	6.69	6.54	6.42	6.31	6.23
10	12.8	9.43	8.08	7.34	6.87	6.54	6.30	6.12	5.97	5.85	5.75	5.66
11	12.2	8.91	7.60	6.88	6.42	6.10	5.86	5.68	5.54	5.42	5.32	5.24
12	11.8	8.51	7.23	6.52	6.07	5.76	5.52	5.35	5.20	5.09	4.99	4.91
15	10.8	7.70	6.48	5.80	5.37	5.07	4.85	4.67	4.54	4.42	4.33	4.25
20	9.94	6.99	5.82	5.17	4.76	4.47	4.26	4.09	3.96	3.85	3.76	3.68
24	9.55	6.66	5.52	4.89	4.49	4.20	3.99	3.83	3.69	3.59	3.50	3.42
30	9.18	6.35	5.24	4.62	4.23	3.95	3.74	3.58	3.45	3.34	3.25	3.18
40	8.83	6.07	4.98	4.37	3.99	3.71	3.51	3.35	3.22	3.12	3.03	2.95
60	8.49	5.80	4.73	4.14	3.76	3.49	3.29	3.13	3.01	2.90	2.82	2.74
120	8.18	5.54	4.50	3.92	3.55	3.28	3.09	2.93	2.81	2.71	2.62	2.54
∞	7.88	5.30	4.28	3.72	3.35	3.09	2.90	2.74	2.62	2.52	2.43	2.36

NOTE : This is for a ***two-tailed test*** with the null and alternate hypotheses shown below:

$$H_o: \; s^2_c = s^2_v$$
$$H_a: \; s^2_c \neq s^2_v$$

Table 5.17.08-1 **Critical Values, F_{crit} , for the F-test for a Level of Significance, α =1 % (contd..)**

DEGREES OF FREEDOM FOR NUMERATOR

DEGREES OF FREEDOM FOR DENOMINATOR

	15	20	24	30	40	50	60	100	120	200	500	∞
1	24600	24800	24900	25000	25100	25200	25300	25300	25400	25400	25400	25500
2	199	199	199	199	199	199	199	199	199	199	199	200
3	43.1	42.8	42.69	42.5	42.3	42.2	42.1	42.0	42.0	41.9	41.9	41.8
4	20.4	20.2	20.0	19.9	19.8	19.7	19.6	19.5	19.5	19.4	19.4	19.3
5	13.1	12.9	12.8	12.7	12.5	12.5	12.4	12.3	12.3	12.2	12.2	12.1
6	9.81	9.59	9.47	9.36	9.24	9.17	9.12	9.03	9.00	8.95	8.91	8.88
7	7.97	7.75	7.65	7.53	7.42	7.35	7.31	7.22	7.19	7.15	7.10	7.08
8	6.81	6.61	6.50	6.40	6.29	6.22	6.18	6.09	6.06	6.02	5.98	5.95
9	6.03	5.83	5.73	5.62	5.52	5.45	5.41	5.32	5.30	5.26	5.21	5.19
10	5.47	5.27	5.17	5.07	4.97	4.90	4.86	4.77	4.75	4.71	4.67	4.64
11	5.05	4.86	4.76	4.65	4.55	4.49	4.45	4.36	4.34	4.29	4.25	4.23
12	4.72	4.53	4.43	4.33	4.23	4.17	4.12	4.04	4.01	3.97	3.93	3.90
15	4.07	3.88	3.79	3.69	3.59	3.52	3.48	3.39	3.37	3.33	3.29	3.26
20	3.50	3.32	3.22	3.12	3.02	2.96	2.92	2.83	2.81	2.76	2.72	2.69
24	3.25	3.06	2.97	2.87	2.77	2.70	2.66	2.57	2.55	2.50	2.46	2.43
30	3.01	2.82	2.73	2.63	2.52	2.46	2.42	2.32	2.30	2.25	2.21	2.18
40	2.78	2.60	2.50	2.40	2.3	2.23	2.18	2.09	2.06	2.01	1.96	1.93
60	2.57	2.39	2.29	2.19	2.08	2.01	1.96	1.86	1.83	1.78	1.73	1.69
120	2.37	2.19	2.09	1.98	1.87	1.80	1.75	1.64	1.61	1.54	1.48	1.43
∞	2.19	2.00	1.90	1.79	1.67	1.59	1.53	1.40	1.36	1.28	1.17	1.00

NOTE : This is for a ***two-tailed test*** with the null and alternate hypotheses shown below:

$$H_o: \quad s^2_c = s^2_v$$
$$H_a: \quad s^2_c \neq s^2_v$$

Case 1: Sample Variances Assumed to Be Equal

a) To conduct the t-test when the sample variances are assumed equal, Equation 1 is used to calculate the t value from which the decision is reached.

$$t = \frac{\left|\overline{X}_c - \overline{X}_v\right|}{\sqrt{\frac{s_p^2}{n_c} + \frac{s_p^2}{n_v}}} \qquad (1)$$

where:
- $\overline{X}_c$ = mean of QC tests
- $\overline{X}_v$ = mean of verification tests
- s_p^2 = pooled estimate for the variance (described below)
- n_c = number of QC tests
- n_v = number of verification tests

b) The pooled variance, which is the weighted average, using the degrees of freedom for each sample as the weighting factor, is computed from the sample variances using Equation 2.

$$s_p^2 = \frac{s_c^2\left(n_c - 1\right) + s_v^2\left(n_v - 1\right)}{n_c + n_v - 2} \qquad (2)$$

Where:
- s_p^2 = pooled estimate for the variance
- n_c = number of QC tests
- n_v = number of verification tests
- s_c^2 = variance of the QC tests
- s_v^2 = variance of the verification tests

c) Once the pooled variance is estimated, the value of t is computed using equation 1.

d) To determine the critical t value against which to compare the computed t value, it is necessary to select the level of significance, α. *A value of $\alpha = 1$ % is recommended.*

e) Determine the critical t value, t_{crit}, from Table 5.17.08-2 for the pooled degrees of freedom. The pooled degrees of freedom for the case where the sample variances are assumed equal is ($n_c + n_v - 2$).

f) If $t \geq t_{crit}$, then decide that the two sets of tests have significantly different means. If $t < t_{crit}$, then decide that there is no reason to believe that the means are significantly different.

Case 2: **Sample Variances Assumed to Be Not Equal**

a) To conduct the t-test when the sample variances are assumed not equal, Equation 3 is used to calculate the t value from which the decision is reached.

$$t = \frac{\left|\bar{X}_c - \bar{X}_v\right|}{\sqrt{\frac{s_c^2}{n_c} + \frac{s_v^2}{n_v}}} \qquad (3)$$

where:

$\bar{X}_c$	=	mean of QC tests
$\bar{X}_v$	=	mean of verification tests
s_c^2	=	variance of the QC tests
s_v^2	=	variance of the verification tests
n_c	=	number of QC tests
n_v	=	number of verification tests

b) To determine the critical t value against which to compare the computed t value, it is necessary to select the level of significance, α. A value of $\alpha = 1\%$ is recommended.

c) The effective degrees of freedom, f', for the case where the sample variances are assumed not equal is determined from Equation 4 *(the calculated effective degrees of freedom is rounded down to a whole number).*

$$f' = \frac{\left(\frac{s_c^2}{n_c} + \frac{s_v^2}{n_v}\right)^2}{\left(\frac{\left(\frac{s_c^2}{n_c}\right)^2}{n_c + 1} + \frac{\left(\frac{s_v^2}{n_v}\right)^2}{n_v + 1}\right)} - 2 \qquad (4)$$

where all the symbols are as described previously.

d) Determine the critical t value, t_{crit}, from Table 5.17.08-2 for the effective degrees of freedom determined by Equation 4.

e) If $t \geq t_{crit}$, then decide that the two sets of tests have significantly different means. If $t < t_{crit}$, then decide that there is no reason to believe that the means are significantly different.

Table 5.17.08-2 Critical t values

degrees of freedom	$\alpha = 0.01$	$\alpha = 0.05$	$\alpha = 0.10$
1	63.657	12.706	6.314
2	9.925	4.303	2.920
3	5.841	3.182	2.353
4	4.604	2.776	2.132
5	4.032	2.571	2.015
6	3.707	2.447	1.943
7	3.499	2.365	1.895
8	3.355	2.306	1.860
9	3.250	2.262	1.833
10	3.169	2.228	1.812
11	3.106	2.201	1.796
12	3.055	2.179	1.782
13	3.012	2.160	1.771
14	2.977	2.145	1.761
15	2.947	2.131	1.753
16	2.921	2.120	1.746
17	2.898	2.110	1.740
18	2.878	2.101	1.734
19	2.861	2.093	1.729
20	2.845	2.086	1.725
21	2.831	2.080	1.721
22	2.819	2.074	1.717
23	2.807	2.069	1.714
24	2.797	2.064	1.711
25	2.787	2.060	1.708
26	2.779	2.056	1.706
27	2.771	2.052	1.703
28	2.763	2.048	1.701
29	2.756	2.045	1.699
30	2.750	2.042	1.697
40	2.704	2.021	1.684
60	2.660	2.000	1.671
120	2.617	1.980	1.658
∞	2.576	1.960	1.645

NOTE : This is for a two-tailed test with the null and alternate hypotheses shown below :

$$H_o : \quad \overline{X}_c = \overline{X}_v$$

$$H_a : \quad \overline{X}_c \neq \overline{X}_v$$

Example Problem 1-Concrete

A contractor has run 21 QC tests for compressive strength and KDOT has run 5 verification tests over the same period of time. The results are shown below. Is it likely that the tests came from the same population?

Contractor QC Test Results (%)	KDOT VerificationTest Results (%)
36.40	36.10
36.65	30.00
32.69	37.00
38.05	32.80
38.54	30.60
37.59	$\overline{X}_v =$ 33.300
36.57	
42.48	
36.99	
38.20	
37.53	
36.00	
41.28	
40.00	
38.37	
38.72	
40.36	
30.37	
34.87	
35.62	
36.06	
$\overline{X}_c =$37.302	

A t-test between the means of these two sets of results can be used to test whether the mean results of the asphalt content tests done by the contractor and KDOT are statistically different. If they are not different, then it is likely that they came from the same population. However, first the F-test needs to be done to determine whether or not to assume the variance of the QC test results differs from the KDOT verification tests.

Step 1. Compute the mean and standard deviation for each set of data:

QC test results	KDOT Verification test results
$\overline{X}_c = 37.302$	$\overline{X}_v = 33.300$
$s_c = 2.736$	$s_v = 3.161$

Step 2. Compute variance, s^2, for each set of test results (variance is square of the standard deviation):

QC test results | KDOT Verification test results

$s_c^2 = 7.431$ $\qquad$ $s_v^2 = 9.992$

Step 3. Compute F, using the largest s^2 in the numerator.

$$F = \frac{s_c^2}{s_v^2} = \frac{9.992}{7.431} = 1.34$$

Step 4. Determine F_{crit} from **Table 5.17.08-1** being sure to use the correct degrees of freedom for the numerator (n_v - 1 = 5 - 1 = 4) and the denominator (n_c - 1 = 21 - 1 = 20).

From Table 5.17.08-1, at α = 1 %, F_{crit} = 5.17

Conclusion: Since F < F_{crit} (i.e., 1.34 < 5.17), there is no reason to believe that the two sets of tests have different variabilities. That is, they could have come from the same population. Since we can assume that the variances are equal, we can use *the pooled variance* to calculate the t-test statistic, and *the pooled degrees of freedom* to determine the critical t value, t_{crit}.

Step 5. Compute the pooled variance, s_p^2, using the sample variances from above.

$$s_p^2 = \frac{s_c^2(n_c - 1) + s_v^2(n_v - 1)}{n_c + n_v - 2}$$

$$s_p^2 = \frac{(7.431)(20) + (9.992)(4)}{21 + 5 - 2} = 7.86$$

Step 6. Compute the t-test statistic, t.

$$t = \frac{\left|\overline{X}_c - \overline{X}_v\right|}{\sqrt{\frac{s_p^2}{n_c} + \frac{s_p^2}{n_v}}}$$

$$t = \frac{|37.302 - 33.300|}{\sqrt{\frac{7.86}{21} + \frac{7.86}{5}}} = \frac{4.002}{\sqrt{1.946}} = 2.87$$

Step 7. Determine the critical t value, t_{crit} , for the pooled degrees of freedom

degrees of freedom = (n_c + n_v -2) = (21 + 5 - 2) = 24.

From **Table 5.17.08-2**,

for $\alpha = 1$ % and degrees of freedom = 24,

$t_{crit} = 2.80$.

Conclusion: Since 2.87 > 2.80, we assume that the sample means are not equal. It is therefore probable that the two sets of test results did not come from the same population (or lot).

Example Problem - Case 2-Asphalt

A contractor has run 10 QC tests and KDOT has run 5 verification tests over the same period of time for the asphalt pavement density (%G_{mm}). The results are shown below. Is it likely that the test came from the same population or lot?

Contractor QC Test Results	KDOT Verification Test Results
93.0	95.5
92.4	93.3
92.9	94.1
93.6	92.5
92.9	92.7
92.9	$\overline{X}_v = 93.62$
92.4	
93.4	
92.9	
92.4	
$\overline{X}_c = 92.88$	

A t-test between the means of these two sets of results can be used to test whether the mean results of the %G_{mm} done by the contractor and KDOT are statistically different. If they are not different, then it is likely that they came from the same population. First, we have to determine whether the variance of the QC tests differ from the verification tests using F-test.

Step 1. Compute the mean and standard deviation for each set of data:

QC test results	KDOT Verification test results
$\overline{X}_c = 92.88$	$\overline{X}_v = 93.62$
$s_c = 0.408$	$s_v = 1.221$

Step 2. Compute the variance, s^2, for each set of tests (variance is the square of the

standard deviation):

$$s_c^2 = 0.166 \qquad\qquad s_v^2 = 1.491$$

Step 3. Compute F, using the largest s^2 in the numerator.

$$F = \frac{s_v^2}{s_c^2} = \frac{1.491}{0.166} = 8.98$$

Step 4. Determine F_{crit} from **Table 5.17.08-1** (be sure to use the correct degrees of freedom for the numerator (n_v - 1 = 5 - 1 = 4) and the denominator (n_c - 1 = 10 - 1 = 9)).

From **Table 5.17.08-1**, at α = 1 %, F_{crit} = 7.96

Conclusion: Since F > F_{crit} (i.e., 8.98 > 7.96), there is reason to believe that the two sets of tests have different variabilities. Thus, it is likely that they came from populations with different variances. Since we CAN NOT assume that the variances are equal, we cannot use the pooled variance to calculate the t-test statistic, and the pooled degrees of freedom to determine the critical t value, t_{crit}.

Step 5. Compute the t-test statistic, t.

$$t = \frac{\left|\overline{X}_c - \overline{X}_v\right|}{\sqrt{\frac{s_c^2}{n_c} + \frac{s_v^2}{n_v}}}$$

$$t = \frac{\left|92.88 - 93.62\right|}{\sqrt{\frac{0.166}{10} + \frac{1.491}{5}}} = \frac{0.74}{\sqrt{0.315}} = 1.32$$

Step 6. Determine the critical t value, t_{crit}, for the approximate degrees of freedom *(the calculated effective degrees of freedom is rounded down to a whole number).*

$$f' = \frac{\left(\frac{s_c^2}{n_c} + \frac{s_v^2}{n_v}\right)^2}{\left(\frac{\left(\frac{s_c^2}{n_c}\right)^2}{n_c + 1} + \frac{\left(\frac{s_v^2}{n_v}\right)^2}{n_v + 1}\right)} - 2$$

$$f' = \frac{\left(\frac{0.166}{10} + \frac{1.491}{5}\right)^2}{\left(\frac{\left(\frac{0.166}{10}\right)^2}{11} + \frac{\left(\frac{1.491}{5}\right)^2}{6}\right)} - 2 = \frac{(0.315)^2}{0.0148} - 2 = 4.7$$

From **Table 5.17.08-2**,

for α = 1 % and degrees of freedom = 4 (rounded down to the nearest whole number)

$t_{crit} = 4.60$

Conclusion: Since $t < t_{crit}$, (i.e., 1.32 < 4.60), there is no reason to assume that the sample means are not equal. It is, therefore, reasonable to assume that the sets of test results came from populations that had the same mean.

Asphalt Paving Excel Spreadsheet

The Air Voids F & t portion of the EXCEL spreadsheet compares the Contractor's Quality Control (QC) results and KDOT's verification results using the following process:

In lots 1 and 2, the mean and standard deviation of the QC results are calculated and compared to the mean of the verification results. The comparison is considered to be satisfactory (Pass) if the mean of the verification results for that lot is within the greater of:

1. the mean of the QC results ± three standard deviations of the QC results for that lot
2. one percent of the mean of the QC results for that lot

Starting with lot 3, the F & t tests are used to compare the QC results and verification results. All of the QC results and verification results are used in the comparison for lots 3, 4 and 5. Starting with lot 6, all of the QC results and verification results for the last five lots are used in the comparison. For example, the test results from lots 2-6 are used in the comparison for lot 6.

The maximum specific gravity (G_{mm}) F & t portion of the EXCEL spreadsheet compares the QC results and verification results using the follow process:

In lots 1 and 2, the mean and standard deviation of the QC results are calculated and compared to the mean of the verification results. The comparison is considered to be satisfactory (Pass) if the mean of the verification results for that lot is within the greater of :

1. the mean of the QC results ± three standard deviations of the QC results for that lot
2. 0.02 of the mean of the QC results for that lot

Starting with lot 3, the F & t tests are used to compare the QC results and verification results. All of the QC results and verification results are used in the comparison for lots 3, 4 and 5. Starting with lot 6, all of the QC results and verification results for the last five lots are used in the comparison. For example, the test results from lots 2-6 are using in the comparison for lot 6.

If the results of comparison of the G_{mm} QC and verification results for a lot are satisfactory (Pass), the QC G_{mm} results should be used in the calculation of %G_{mm} for both the QC and verification Density results. If the results of the comparison of the G_{mm} QC and verification results for a lot are not satisfactory (Fail), the verification G_{mm} results should be used in the calculation of %G_{mm} for both the QC and verification Density results.

The Density F & t portion of the EXCEL spreadsheet compares the QC results and verification results using the follow process:

All of a lot's QC results and verification results are used in the comparison for that lot. Each lot stands on its' own for the Density F & t comparison.

For the Air Voids, G_{mm} and Density F & t comparisons, the results are considered satisfactory (Pass) if the t-test shows that the Contractor's QC results and KDOT's QA results are from the same population with a α of 1%.

Concrete Paving Excel Spreadsheet

The Compressive Strength and Thickness F & t portions of the EXCEL spreadsheet compare the Contractor's Quality Control (QC) results and KDOT's verification results using the following process:

In lots 1 and 2, the mean and standard deviation of the QC results are calculated and compared to the mean of the verification results. The comparison is considered to be satisfactory (Pass) if the mean of the verification results for that lot is within the mean of the QC results ± three standard deviations of the QC results for that lot.

Starting with lot 3, the F & t tests are used to compare the QC results and verification results. All of the QC results and verification results are used in the comparison for lots 3, 4 and 5. Starting with lot 6, all of the QC results and verification results for the last five lots are used in the comparison. For example, the test results from lots 2-6 are used in the comparison for lot 6.

For the Compressive Strength and Thickness F & t comparisons, the results are considered satisfactory (Pass) if the t-test shows that the Contractor's QC results and KDOT's QA results are from the same population with a α of 1%.

F & t Air Void Spreadsheet for 90M-6656

90M-6656

Lots:	1	8	Project #	96 K-4459-01	Name of QC Tester	Lora Kovach
Dates:	4/07/2000	5/14/2000	Contract #	595116765	Certification # of QC Tester	712000

SM-19A		Air Voids							
Lot	Date	Contractor Quality Control Tests (%)	KDOT Verification Test (%)	Number of Contractor Tests	Number of KDOT Tests	T Test	T(crit)	Are Means The Same?	Use Contractor Test Results?
1A	4/07/2000	3.20							
1B	"	3.50							
1C	4/14/2000	2.60	4.23						
1D	"	5.40							
1E									
1F				4	1			Pass	yes
2A	"	3.90							
2B	"	5.60							
2C	4/15/2000	1.70							
2D	4/16/2000	3.60	5.15						
2E									
2F				4	1			Pass	yes
3A	"	2.20							
3B	4/18/2000	2.00							
3C	"	2.00	4.98						
3D	4/21/2000	2.30							
3E									
3F				12	3	2.07	3.01	Pass	Yes
4A	4/22/2000	4.30							
4B	"	3.75							
4C	"	4.05							
4D	4/23/2000	4.80	5.15						
4E									
4F				16	4	2.28	2.88	Pass	yes
5A	4/24/2000	4.90							
5B	4/25/2000	5.07							
5C	"	3.83							
5D	4/28/2000	3.53							
5E									
5F				20	4	2.07	2.82	Pass	yes

F & t Density Spreadsheet for 90M/P-230-R7

90M/P-230-R7

Lots:	1	7	Project #	96 K-4459-01	Name of QC Tester	Lora Kowach
Dates:	4/7/2000	4/22/2000	Contract #	595116765	Certification # of QC Tester	712000
Mix Type	SM-19A					

Lot	Date	Contractor Test Results (kg/m3)	Gmm	Contractor Quality Control Tests (%Gmm)	KDOT Test Results (kg/m3)	KDOT Verification Tests (%Gmm)	Number of Contractor Tests	Number of KDOT Tests	T Test	T(crit)	Are Means The Same?
1A1	4/07/2000	2070	2.398	86.58	2241	93.73					
1A2	4/07/2000	2161		90.38							
1B1	4/07/2000	2180		91.18	2175	90.97					
1B2	4/07/2000	2080		87.00							
1C1	4/07/2000	2140		89.51	2143	89.63					
1C2	4/07/2000	2240		93.69							
1D1	4/07/2000	2161		90.38	2215	92.64					
1D2	4/07/2000	2120		88.67							
1E1	4/07/2000	2180		91.18							
1E2	4/07/2000	2120		88.67			10	4	1.67	3.05	Pass
2A1	4/14/2000	2255	2.432	93.00	2315	95.47					
2A2	4/14/2000	2240		92.38							
2B1	4/14/2000	2253		92.91	2263	93.33					
2B2	4/14/2000	2270		93.62							
2C1	4/14/2000	2253		92.91	2282	94.11					
2C2	4/14/2000	2253		92.91							
2D1	4/14/2000	2241		92.42	2243	92.50					
2D2	4/14/2000	2263		93.33							
2E1	4/14/2000	2253		92.91	2248	92.71					
2E2	4/14/2000	2243		92.50			10	5	1.33	4.60	Pass
3A1	4/15/2000	2173	2.430	89.69	2373	97.94					
3A2	4/15/2000	2184		90.14							
3B1	4/15/2000	2239		92.41	2375	98.03					
3B2	4/15/2000	2236		92.29							
3C1	4/15/2000	2211		91.26	2374	97.99					
3C2	4/15/2000	2216		91.46							
3D1	4/15/2000	2283		94.23	2379	98.19					
3D2	4/15/2000	2185		90.18							
3E1	4/15/2000	2229		92.00	2401	99.10					
3E2	4/15/2000	2230		92.04			10	5	10.58	3.01	Fail

F & t G_{mm} Spreadsheet for 90M/P-230-R7

90M/P-230-R7

Lots:	1	8	**Project #**	96 K-4459-01	**Name of QC Tester**	Lora Kowach
Dates:	4/07/2000	5/14/2000	**Contract #**	595116765	**Certification # of QC Tester**	712000

SM-19A		Gmm							
Lot	Date	Contractor Quality Control Tests (Gmm)	KDOT Verification Test (Gmm)	Number of Contractor Tests	Number of KDOT Tests	T Test	T(crit)	Are Means The Same?	Use Contractor Test Results?
1A	4/07/2000	2.410							
1B	"	2.386							Yes
1C	4/14/2000	2.441	2.421						
1D	"	2.430							
1E									
1F				4	1			Pass	
2A	"	2.425							
2B	"	2.432							Yes
2C	4/15/2000	2.433	2.427						Yes
2D	4/16/2000	2.443							
2E									
2F				4	1			Pass	
3A	"	2.441							Yes
3B	4/18/2000	2.437	2.408						
3C	"	2.429							Yes
3D	4/21/2000	2.410							Yes
3E									
3F				12	3	0.76	3.01	Pass	
4A	4/22/2000	2.429							
4B	"	2.419							
4C	"	2.402	2.406						Yes
4D	4/23/2000	2.433							Yes
4E									
4F				16	4	1.13	2.88	Pass	
5A	4/24/2000	2.431							Yes
5B	4/25/2000	2.432	2.427						
5C	"	2.433							Yes
5D	4/28/2000	2.424							
5E									
5F				20	5	1.20	2.81	Pass	

F & t Compressive Strength Spreadsheet

90 M/P-244

Lots:	1	5	**Project #**	70-99 K5663-01	**Name of QC Tester**	Randy
Dates:	9/5/2000	9/14/2000	**Contract #**	599021021	**Certification # of QC Tester**	110909

Lot	Date	Corrected Contractor Compressive Strength (MPa)	Corrected KDOT Compressive Strength (MPa)	Number of Contractor Tests	Number of KDOT Tests	T Test	T(crit)	Are Means The Same?	Use Contractor Test Results?
1A1	9/5/2000	35.58	42.54						
1A2	"								
1B1	"	37.09							
1B2	"								
1C1	"	33.02							
1C2	"								
1D1	"	31.13							
1D2	"								
1E1	"	39.91							
1E2	"			5	1			Pass	**Yes**
2A1	9/6/2000	39.20							
2A2	"								
2B1	"	31.98	48.39						
2B2	"								
2C1	"	36.88							
2C2	"								
2D1	"	42.15							
2D2	"								
2E1	"	37.14							
2E2	"			5	1			Pass	**Yes**
3A1	9/7/2000	33.27							
3A2	"								
3B1	"	34.39	25.38						
3B2	"								
3C1	"	32.27							
3C2	"								
3D1	"								
3D2	"								
3E1	"								
3E2	"			13	3	0.44	9.92	Pass	**Yes**
4A1	9/8/2000	31.28							
4A2	"								
4B1	"	34.62							
4B2	"								
4C1	"	38.69							
4C2	"								
4D1	"	40.68	30.69						
4D2	"								
4E1	"								
4E2	"			17	4	0.17	5.84	Pass	**Yes**
5A1	9/12/2000	36.53							
5A2	"								
5B1	"	42.97	29.51						
5B2	"								
5C1	"	35.95							
5C2	"								
5D1	"	32.65							
5D2	"								
5E1	"								
5E2	"			21	5	0.17	4.60	Pass	**Yes**

F & t Thickness Spreadsheet

90 M/P-244

Lots:	1	5	**Project #**	70-99 K5663-01	**Name of QC Tester**	Randy
Dates:	9/5/2000	9/14/2000	**Contract #**	599021021	**Certification # of QC Tester**	110909

Lot	Date	Contractor Core Length (mm)	KDOT Core Length (mm)	Number of Contractor Tests	Number of KDOT Tests	T Test	T(crit)	Are Means The Same?	Use Contractor Test Results?
1A1	9/5/2000	276							
1A2	"								
1B1	"	280	295						
1B2	"								
1C1	"	263							
1C2	"								
1D1	"	277							
1D2	"								
1E1	"	278							
1E2	"			5	1			Pass	**Yes**
2A1	9/6/2000	284							
2A2	"								
2B1	"	268	285						
2B2	"								
2C1	"	260							
2C2	"								
2D1	"	258							
2D2	"								
2E1	"	268							
2E2	"			5	1			Pass	**Yes**
3A1	9/7/2000	292							
3A2	"								
3B1	"	302	326						
3B2	"								
3C1	"	297							
3C2	"								
3D1	"								
3D2	"								
3E1	"								
3E2	"			13	3	2.55	2.98	Pass	**Yes**
4A1	9/8/2000	295							
4A2	"								
4B1	"	294	315						
4B2	"								
4C1	"	282							
4C2	"								
4D1	"	298							
4D2	"								
4E1	"								
4E2	"			17	4	2.97	2.86	Fail	**No**
5A1	9/12/2000	311							
5A2	"								
5B1	"	286							
5B2	"								
5C1	"	298							
5C2	"								
5D1	"	286	289						
5D2	"								
5E1	"								
5E2	"			21	5	2.45	2.80	Pass	**Yes**